Magnetic Shielding in Hall Thrusters

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A proof-of-principle effort to demonstrate a technique by which erosion of the acceleration channel in Hall thrusters can be eliminated has been completed successfully. The first principles of the technique, now known as “magnetic shielding,” were derived based on the findings of numerical simulations with the Hall2De code. The simulations, in turn, guided the modification of an existing 6-kW laboratory Hall thruster to test the theory. Because neither theory nor experiment alone can validate fully the first principles of the technique, the objective of the 2-yr effort was twofold: (1) to demonstrate in the laboratory that the erosion rates can be reduced by at least two orders of magnitude, and (2) to demonstrate that the near-wall plasma properties can be altered according to the theoretical predictions. Both objectives have been accomplished. Near the walls of the magnetically shielded (MS) thruster theory and experiment agree: (1) the plasma potential has been sustained at values near the discharge voltage, and (2) the electron temperature has been lowered compared to the unshielded (US) thruster. Erosion rates deduced directly from the wall probes show reductions of at least ~3 orders of magnitude at the MS inner wall when an ion energy threshold of 30.5 V is used in the sputtering yield model of the channel material. At the outer wall the probes revealed that the ion energy was below the assumed threshold. Using a threshold of 25 V, the simulations predict a minimum reduction of ~600 at the MS inner wall. At the MS outer wall ion energies are found to be below 25 V. When a 50-V threshold is used the computed ion energies are below the threshold at both sides of the channel. Uncertainties, sensitivities and differences between theory and experiment are also discussed. Collectively, the comparisons between the numerical simulation results and the measurements provide strong evidence that the first principles of magnetic shielding are now well understood and can be applied to reduce erosion in Hall thrusters by at least a few orders of magnitude. These findings have significant and immediate implications on space programs worldwide. The elimination of wall erosion in Hall thrusters solves a problem that has remained unsettled for more than five decades, allowing for new space exploration missions that could not be undertaken in the past.